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Support of Pupil's Creative Thinking in Mathematical Education

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Abstract

Creativity is an essential feature of personality that is used in everyday life. It allows us to be flexible when dealing with real life situations. Mathematical education should be seen as one of opportunities for creativity development, although creativity is not traditionally associated with maths. One of the education goals at any school level should be to encourage pupils to think creatively, think logically and to be able to solve problems. We describe activities suitable for different school levels in this paper. We use brainstorming in mathematical education. When creating problems we cooperated with student in the age of 13 and 14. We asked them to look for "any geometry" and take photos of interesting objects as they walk at the playground. Next, students create ideas for geometrical tasks based on taken photos. Rich collection of collected photos represents the base for the creation of mathematical problems, without specific measures related to geometrical objects. These open problems could be completed and solved by students.

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1. Introduction

Creativity is an essential feature of personality that is used in everyday life. Creativity allows us to be flexible when dealing with real life situations. Mathematical education should be seen as one of opportunities for creativity development, although creativity is not traditionally associated with mathematics.

Due the difficulty of describing the structure of mathematical creativity and its characteristics, defining mathematical creativity is a challenging task (Nadjafikhah, Yaftian, & Bakhshalizadeh, 2012).

One of the main aims of mathematical education is preparing students for dealing effectively with the real-life situations. The effect of activity in this area in Holland was the *Realistic Math Education theory* created by H. Freudental (Heuvel-Panhuizen, 1998). We can find a lot of mathematics around us. The world around us provides many opportunities to come up with mathematical tasks that are based on everyday situations.

Mathematics is an integral part of the real-life not only for many daily activities but also for a wide variety of work situations. It is necessary to transfer the math knowledge and skills gained in schools to the real-life that

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2. Mathematical Creativity and Van Hiele's Theory

Laycock described mathematical creativity as an ability to analyze a given problem from a different perspective, see patterns, differences and similarities, generate multiple ideas and choose a proper method to deal with unfamiliar mathematical situations (as cited in Nadjafikhah et al., 2012).

Silver claims that creative thinking can be developed by open-ended questions. Meissner puts emphasis on the idea that creative thinking can be developed through challenging questions. Fisher draws attention to the necessity of question related to daily life in creative thinking (as cited in Kandemir & Gür, 2009).

According to Van Hiele's theory of geometrical thought there are five levels of geometrical understanding:

Level 1 (Visualization): Students recognize figures by appearance alone, often by comparing them to a known prototype. Properties of a figure are not perceived. Students make decisions based on perception, not reasoning.

Level 2 (Analysis): Students see figures as collections of properties and can recognize and name properties of geometric figures, but they do not see relationships between these properties. When students describe an object they might list all the properties they knows, but not discern which properties are necessary and which are sufficient to describe the object.

Level 3 (Abstraction): students perceive relationships between properties and between figures. They can create meaningful definitions and give informal arguments to justify their reasoning. Students understand logical implications and class inclusions, e.g. a square is a type of rectangle. However, they do not understand the role and significance of formal deduction.

Level 4 (Deduction): Students can construct proofs, understand the role of axioms and definitions, and know the meaning of necessary and sufficient conditions. Students should be able to construct proofs like those typically found in high school geometry classes.

Level 5 (Rigor): Students understand the formal aspects of deduction, e.g. establishing and comparing mathematical systems. They can understand the use of indirect proof and proof by contrapositive and can understand non-Euclidean systems. (Mason, 1999)

The results of study of Guzel and Sener (2009) show that spatial ability (three-dimensional thinking) improves students' understanding of symbols, shapes, tables, and figures. Besides, it assists students in comprehending drawings easily, commenting the visualized information, creating contexts among different concepts easily, generalizing complex concepts, and thinking in different ways. Spatial ability plays a crucial role in mathematics success, especially in geometry as it is based on the visualization.

require the individual to reason, calculate, estimate or apply math knowledge to solve real-life problems and also to communicate mathematically (Baki, Çatlıoğlu, Coştu, & Birgin, 2009).

3. Geometry on the playground from the student point of view

We cooperated with 13 and 14 years old students. We asked them to look for "any geometry" and take photos of interesting objects as they walk at the playground. Next, we asked them to try to create ideas for geometrical tasks based on taken photos. We obtained a rich collection of photographs by this activity. These photos represent the base for the creation of mathematical problems, without specific measures related to geometrical objects. These open problems could be completed and solved by students.

3.1. Students photos with mathematical ideas

The main goal during the creation of problems was to develop students' dynamical mathematical thinking and skills to create mathematical tasks. To create specific tasks, students can complete the measure of shape in the photo

- by estimating according to their own experiences,
- by approximating to similar real objects,
- by measuring concrete picture and adapting it in appropriate gauge,
- by searching similar object it their environment and measure it.

In the next section we describe problems that could be perceived as the motivation for activities ideas. These problems lead us to create mathematical tasks and provide space for solvers´ own creativity.

Figure 1:a) tree stump shaped as oblique cylinder ,b) plinth for decorative pillar shaped as regular 6-sides' prism, c) one of climbing frames in the playground, which is part of the half-cylinder

Students created many geometrical tasks. What could be the volume of the missing tree bark, if its thickness was 8% of its radius? What could be the maximum distance between ground and the ant which is walking on the tree stump? What could be the weight of sawdust which we could get from this whole stump if its wood density is 690kg/m^3. (Figure 1a)

Students' tasks created to the figure 1b): How many litters of concrete are possible to pour into the pillar? How many small stones were needed for decorating exterior ...., if average area covered by one stone is 7cm^2? In many ways can the stand be divided into two equal parts?

There is one of the climbing frames in the playground which is part of half-cylinder in the picture 1c). Students wanted to find out how many kilometers of rods could be obtained if all the bars of climbing frame are connected together. Other geometrical tasks can be: What would be an area in the geometric plane if you draw the holes in the square grid? How many meters of rods would be needed for the construction of the climbing frame? The half-cylinder should remain consistent with its height. How many kilograms of yellow and red colour is needed for coating bars of climbing frame if we know the average price of a color bar for one square meter?

3.2. Solving problems using the GeoGebra software

In the second part of the article, we chose problems with specific assignments created. New trends in mathematics lead to the use variety of educational software to improve teaching and make it more attractive. To solve problems we used the GeoGebra dynamic software. We suppose that we have chosen the appropriate mathematical software and show students more attractive form of mathematics. It is an appropriate tool for teaching mathematics in elementary schools, high schools and universities. By using this software, we wanted to highlight the dynamic elements which can affect the result or the number of solutions to the problem.

Pillar in the picture (Figure 2a) is on a pier at the pond and serves to attach the boat. Pillar, its shadow and the rope that we could stretch out between them, form a triangle.

- How does the length of the rope depend on the length of the shadow? When is the length of the shadow minimal and maximal?
- How does the length of the rope depend on its attachment to the pillar?

The length of the pillar shadow depends on the position of the Sun. We can use this feature to solve the first part of the task. In the GeoGebra, this situation can be presented by the movement of point *S* (which represents the Sun) in a circle with radius equal to the distance between the Sun and the Earth. The situation in the fig. 1 is a model in which we neglect the position of the shadow and focus on its length. This allows us to simulate 3D phenomenon in the plane; also the radius of the Earth and the Sun are neglected (Figure 2b).

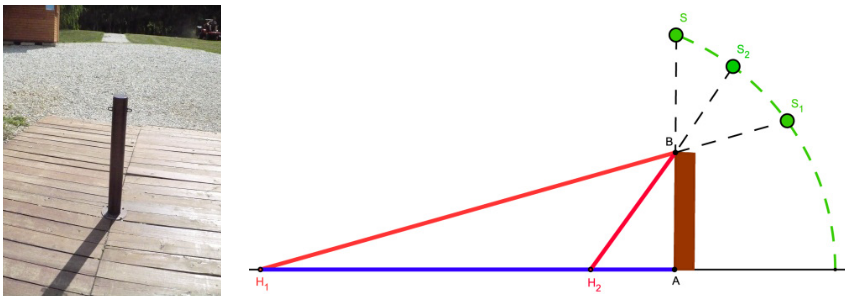

Figure 2: a) Student's photo, b) Solution of task using the GeoGebra

Next photo shows signs placed at the beginning of the playground (Figure 3a). Task: Redraw middle part of the road sign into the square grid. The length of the boxes should be the same length as the distance between two quarters of the circles. Sides of the rectangle are in the ratio and the length of the shorter sides of the rectangle would be half the length of the box.

Using the GeoGebra we repainted quadrant and the rectangle by putting them into selected grid. One of the advantages of this software is the ability to replay given constructions, and thereby to rethink the didactical process of work with the students in advance. We are also able to check the solution and work with software to view the construction in praxis (Figure 3b).

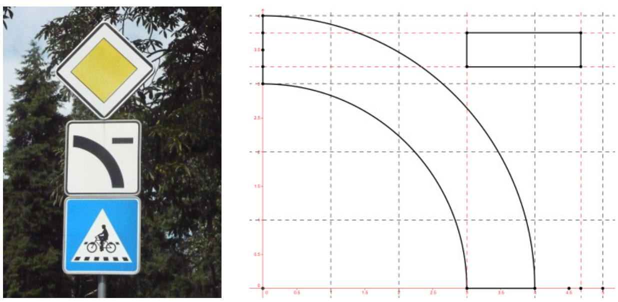

Figure 3: *a) Student's photo, b) Solution of task using the GeoGebra*

4. Conclusion

One of the goals of education at any school level should be to encourage pupils to think creatively, think logically and to be able to solve problems. Švecová and Rumanová (2012) mentioned that creative thinking can be developed by a creative teacher who would help to form creative situations, support pupils' initiative and give space to new and original ideas. By supporting mathematical creativity, we can provide a combination of knowledge and real life situations. Solving mathematical problems can be done by supporting pupils to be active and creative. A highly suitable thing to do would be to look for mathematics in all that surrounds us. Pupils should look for mathematical properties, patterns, geometric shapes or bodies in the city, at home, in nature and so on.

In our opinion, a good activity appears to be finding mathematics in the environment of the park, which is a rich collection of such information. We can apply it at different age of pupils, but also in all areas of mathematics.

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